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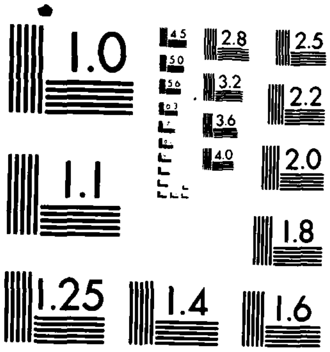

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AD-A161 952

ANALYSIS OF THE COST EFFECTIVENESS AND APPLICABILITY OF THE RELIABILITY TASKS OF MIL-STD-785B

Thesis

Caren E. Atterbury
Captain, USAF

AFIT/GSM/LSY/85S-1

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AFIT/GSM/LSY/85S-1

ANALYSIS OF THE COST EEFECTIVENESS AND APPLICABILITY OF THE RELIABILITY TASKS OF MIL-STD-785B

THESIS

Presented to Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Systems Management

Caren E. Atterbury, B.S.
Captain, USAF

September 1985

Preface

The original purpose of this thesis was to develop a handbook that could be used by reliability engineers tasked with including reliability tasks in an acquisition contract. However the Product Assurance Handbook written by the Columbia Research Corporation was sent to my advisor while I was writing this thesis. The discovery of the handbook caused the whole focus of this project to change because the handbook completely accomplished the initial intent for both reliability and maintainability tasks. Instead of citing actual statements to include in the SOW, as originally intended, the reasons why these statements/tasks should or should not be included became paramount. I had already changed my topic once, thus this refocus was yet another stumbling block to overcome.

With help and encouragement from my thesis advisor Captain Clint Campbell, and readers Mr. Roy Wood and Mr. Mike Schubert I managed to complete this project. They well deserve and have my sincere appreciation.

I must also recognize my husband, Skip, who kept asking me when my thesis would be finished, knowing full well it would not be done until it was due.

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Abstract

This thesis analyzed the cost effectiveness of the 18 tasks specified in MIL-STD-785B, Reliability Program for Systems and Equipment Development and Production. The purposes of the tasks are described and each task was evaluated according to six criteria. Cost effectiveness tables were developed for Airframe/Mechanical Equipment, Avionics/Electrical Equipment, and Space and Missile Systems. The tables shows averages taken from surveys completed by reliability instructors teaching at AFIT and reliability engineers employed by Aeronautical Systems Division and Air Force Aquisition Logistics Center. This analysis also includes a discussion of the applicability of the tasks according to program phase.

ANALYSIS OF THE COST EFFECTIVENESS AND APPLICABILITY
OF THE RELIABILITY TASKS OF MIL-STD-785B

I. Research Problem

Introduction

Reliability is a concept that has attracted quite a lot of attention recently, not only in the military but throughout industry. Why such concern?

In the past, development of a weapon system was primarily concerned with cost, schedule and performance. If these parameters were met, a program was initially considered a success. However if the system was unreliable, (ie. it broke down consistently) maintenance and spare parts' costs (life cycle costs) escalated. The original acquisition schedule may have been met but planned operational schedules must be discarded. Performance is worthless unless a system is operating.

Thus reliability is of considerable interest (or should be) to any organization dealing with weapon systems or equipment of any kind. Reliability of systems has been mandated for some time by policy letters originating at the Secretary of Defense level and reinforced at lower echelons of command throughout the Department of Defense (DOD) and the Air Force (AF). The following quote is from a policy letter dated 16 August 1974 signed by General Phillips, Commander of Air Force Systems Command (AFSC):

> Reliability considerations are as important to a successful development program as cost, schedule or performance and are equally deserving of your attention (7).

This next quote is from the Action Memorandum signed by both General Gabriel, Chief of Staff of the Air Force and Vern Orr, Secretary of the Air Force dated 17 September 1984:

> For too long, the reliability and maintainability of our weapon systems have been secondary considerations in the acquisition process. ... Reliability and maintainability must be coequal with cost, schedule and performance as we bring a system into the Air Force inventory. (10)

An outcome from the Action Memorandum was a study group and an HQ USAF action plan titled R&M 2000, dated 1 February 1985. The plan's objective is to ensure "that reliability and maintainability (R&M) are considered across all weapon systems and treated equally with cost, schedule, and performance" (16:1). For this plan to succeed, it is mandatory that the R&M requirements are properly stated and all relevant specifications are referenced in the contract.

In addition to policy letters over the years, there have been voluminous reports and regulations covering the need for reliability, but there seems to be a problem in actually contracting for reliability. In order to build/develop a useful and reliable system specific reliability requirements must be developed and communicated to the contractor.

R&M is often used as one word and both reliability and maintainability affect each other. However:

> Reliability is a relatively independent discipline that should not be confounded with maintainability. Reliability is positive. Maintainability is negative, (except for preventive maintenance), a spillover from imperfect reliability. In short, if perfect reliability is achieved; nothing needs to be repaired. (22:25)

Realistically, perfect reliability is almost impossible, thus maintainability is a necessary part of any program. However in order to narrow the scope of research, only contracting for reliability shall be the subject of this paper.

Problem Statement

A problem occurs when inexperienced people are assigned the task of developing the reliability criteria for a contract. When is it appropriate to require the tasks specified in Military Standard (MIL-STD) 785B, Reliability Program for Systems and Equipment Development? How cost effective are the tasks? In order to answer these questions an analysis of each task was done to determine the task's applicability in each acquisition phase and its cost effectiveness.

Background

The DOD has defined reliability in MIL-STD-721C, Definitions of Terms for Reliability and Maintainability. Reliability is:

> (1) The duration or probability of failure-free performance under stated conditions.
> (2) The probability that an item can perform its intended function for a specified interval under stated conditions. (11:54)

According to this definition reliability is simply the fact that something works as intended.

However the reliability intentions are not always stated or may be stated incorrectly. A contractor cannot be obligated to produce a more reliable system than that which is specified. Reliability specifications must be clearly stated but not so binding as to inhibit creativity in design.

Reliability is a performance parameter and needs to be designed into the system. Once a system has been designed and built, it is possible and necessary to test that system's reliability. Testing will not increase reliability, since reliability will only change from a redesign. Testing is important however and needs to be continuous from the beginning of the system aquisition process. For testing produces failures which, when analyzed, can indicate where redesign is necessary. If a deficiency in reliability is discovered early enough it is possible to redesign with minimal cost. Also, screening (the operation to identify and remove bad parts) is sometimes considered a test and can help improve the overall quality (or reliability) of the product by elimination of failed components.

Reliability is designed into the product by having a good Reliability Program. And the Program is structured in the contract. The original intent of this thesis was to develop a Contracting for Reliability Primer to be used as a guide to help AF project managers correctly state in the contract the reliability tasks required. However during the course of this study the Product Assurance and Test Engineers Contracting Handbook was discovered. The Columbia Research Corporation published this handbook in 1982 under the auspices of the Army. This handbook gives specific examples of how to include the various tasks of MIL-STD-785B into the Statement of Work (SOW). The handbook essentially covers the exact area intended to be covered by this thesis. Therefore the focus of this project changed to analyzing the cost effectiveness of each of the tasks and identifying the appropriate time in the acquisition cycle to apply the task.

Scope of Research

The scope of this research effort is limited to analysis of the application of the 18 tasks of MIL-STD-785B. This thesis deals specifically with the cost effectiveness and timing of the application of the tasks in an acquisition contract.

This effort does not attempt to cover all the aspects of a reliability program that are usually present in successful management of reliability of an acquisition project. It will be assumed that a Statement of Need and Specification will have already been published, thus reliability goals will have been determined and the chosen contractor should be committed to meeting the reliability requirements.

Methodology and Format

This section describes the methodology used for the research project and the format of this thesis.

Methodology for Research. The methodology used for this research encompassed personal interviews, a literature review, and an analysis of the cost effectiveness of reliability tasks.

The interviews were of reliability engineers involved in contracting for reliability. These interviews were unstructured and used as background for understanding of the many aspects of contracting for reliability. Relevant regulations and published guidelines were used to determine necessary aspects of a contract to ensure reliability. Also contracts already in force were acquired and used as additional background.

A cost effectiveness chart was developed based on the "Cost Effectiveness Influences" table in Military Handbook (MIL-HDBK) 338, Electronic Reliability Design Handbook (12). Individuals familiar with contracting for reliability were asked to fill in the chart based on their subjective view of the cost effectiveness of tasks taken from MIL-STD-785B. Each task was evaluated according to the six criteria used in MIL-HDBK-338.

Thesis Format. The format of this thesis consists of five chapters and the appendix. This first chapter contains the introduction, problem statement, background, the methodology used in the research and the format of this thesis.

Chapter II contains the literature review, which concentrates primarily on the regulations, MIL-STDs and other pertinent reliability handbooks and guides. In addition a brief historical background of the reliability efforts by the military is also presented.

Chapter III discusses each task of MIL-STD-785B by describing the purpose of the task.

In Chapter IV the results from the cost effectiveness surveys are presented and the relative value of each task is analyzed. The four acquisition phases are described and the applicability of the reliability tasks according to program phase is discussed. The tasks that are relevant for each phase are identified.

The concluding Chapter V summarizes this thesis and gives recommendations for future efforts in the reliability/contracting area.

II. Literature Review

This chapter presents the review of pertinent literature on the subject of systems reliability and how best to contract to achieve reliability. Because of the vastness of the literature currently available on reliability, some constraints were necessarily imposed on the literature review. Thus this review deals primarily with applicable directives, regulations, and standards. However numerous articles, reports and guides are also included for they were found to be quite helpful as background information.

Historical Aspects of Reliability

A paper by Thomas Musson titled "A Reliability Chronology" gives a succinct view of the shifts of emphasis of defense reliability activities beginning in the 1950's. He cited the evolution of the actual goals or objectives that reliability of systems should achieve. ("The reliability activities are only means to achieve an identified end...reliability...itself is not a goal that is sought.") (24:14)

The objectives evolved from increasing operational time, through enhancing mission performance and keeping Life Cycle Costs (LCC) down, to achieving combat readiness, which Musson feels is the present emphasis. However the emphasis on readiness is changing to

> an increase in the attention placed on the technical manpower and skill levels required within the defense

> establishment. ...with an increased emphasis on reliability as a means of decreasing the demand for the number of technicians and the demand for high skill levels. (24:15)

The above quote actually defines supportablility, which becomes increasingly less costly as reliability increases.

The shifts of emphasis occurred through periodic reviews and examinations. DOD Directive 5000.40, Reliability and Maintainability, published in 1980, was an attempt to correct deficiencies and achieve better reliability by focusing "more attention on the design engineering aspects of reliability as opposed to the numerical aspects" (24:16).

During the fifties the science of reliability concentrated on numbers, and the attempt to define reliability by numbers. It was during this period that the statistics and the building of models for reliability actually began. In the late 1960's the concentration was on reliability demonstrations through testing. A problem was found with this type of testing:

> ...the reason that reliability demonstrations do not guarantee acceptable reliability in the field is that the test environments do not simulate the field environment (24:17).

Thus the Combined Environment Reliability Test (CERT), in the early 1970's, was used to try to introduce realistic environments in testing. CERT is an attempt to simulate real environments by simulataneously inducing temperature cycling, vibration, and changes in humidity.

Another panacea cited by Musson which was supposed to forever eliminate the problem of poor reliability was the warranty, or more specifically the Reliability Improvement Warranty (RIW) first advocated in the 1970's.

> The RIW plan commits the contractor to perform stipulated depot-type repair services for a fixed operating time, calendar time, or both, at a fixed price (12: Sec 12, 19).

The objective of the RIW is "to secure reliability improvement and reduce support costs" (12: Sec 12, 19). The RIW has been determined to be an effective tool but it is "inappropriate to some procurements and that the use of a RIW would not guarantee a motivated contractor" (24:17).

MIL-HDBK-338, Electronic Reliability Design Handbook, describes 23 different product performance agreements that can be applied to DOD contracts, with warranties-guarantees agreements being the most commonly applied by the DOD (12:12-14 to 12-18). As brought out by Mary Ann Gilleece, Former Deputy Under Secretary of Defense for Acquisition Manage-ment, all warranties cost money.

> Use of warranties should be applied on a case-by-case basis and should reflect a balance of risk between the government and the contractor and the attendant cost considerations (21:28).

Since the RIW did not solve all reliability problems, to simplify the process and try to get reliability by design, was emphasized as another panacea. A good paper design is an essential element of a successful reliability program but does not guarantee the successful performance of a product in the field. (24:17) Today there is not one method that guarantees reliability. A good program which takes into consideration the many avenues available however does have a good chance of success.

Directives, Regulations and Standards

This section outlines the directives, regulations and military standards (MIL-STD's) applicable for any AF reliability program and judged most applicable and/or useful to this thesis.

Department of Defense Directive (DODD) 5000.1, Major Systems Acquisitions (13), is the governing directive for acquiring major weapon systems. Achieving reliability is specified to be included as a precept for management to apply throughout the acquisition process.

DODD 5007.40, Reliability and Maintainability (15), establishes policies and responsibilities for R&M. According to this directive the major objectives of defense R&M activities are to increase operational effectiveness, reduce life cycle costs (LCC) and manpower requirements, provide information and operate in an efficient manner. DOD 5000.40 directs program managers and acquiring activities to integrate and tailor, allocate, address, and enforce and correct deficiencies of R&M engineering tasks and tests. This is the official guideline for all R&M programs. Subsequent lower echelon regulations should be based on DOD 5000.40.

Department of Defense Instruction (DODI) 5000.2, Major System Acquisition Procedures (14), implements DODD 5000.1. Section 9 of DODI 5000.2 deals with reliability and maintainability (R&M), stating that goals and thresholds of R&M should directly relate to "operational readiness, mission success, nuclear and nonnuclear survivability and endurance, maintenance manpower cost, and logistic support cost" (14:16). The instruction also calls for reliability growth to be "predicted and graphically displayed" (14:17) for reviews, and resources for design corrections to be identified.

Air Force Regulation (AFR) 800-18, "Air Force Reliability and Maintainability Program" (5), is the AF regulation that implements DODD 5000.40. It

> establishes policy to ensure every Air Force system is available when needed, will perform its assigned missions, and can be operated and supported economically (5:1).

This regulation primarily assigns responsibility for R&M by designating specific requirements and objectives for each of the following organizations:

HQ USAF/LE - Deputy Chief of Staff for Logistics

HQ USAF/RD - Deputy Chief of Staff for Research and Development

The Implementing Command

HQ AFSC - Headquarters Air Force Systems Command

HQ AFLC - Headquarters Air Force Logistic Command

The Operating Command

AFTEC - Air Force Test & Evaluation Center (Now known as AFOTEC - Air Force Operational Test and Evaluation Center)

Air Force Systems Command (AFSC) Supplement 1 to AFR 800-18 (6) is AFSC's implementation of its R&M requirements designated by AFR 800-18. This supplement details the responsibilities of a program manager, states R&M training is required by engineers assigned R&M responsibility and goes into detail on the many tasks and tests necessary for a viable reliability program. This supplement also delineates the responsibilities of the various divisions within AFSC.

Air Force Logistics Command (AFLC) Supplement 1 to AFR 800-18 (4) is AFLC's implementation of its R&M requirements designated by AFR 800-18. AFLC's supplement is a short document (only one page) which primarily assigns R&M responsibilities to the AFLC organizations while leaving the details up to those organizations.

Electronic System Division Regulation (ESDR) 800-5, Reliability Program for Systems and Equipment Development and Production (3) is an attempt by a major product division to standardize how to contract for reliability.

ESD Product Assurance Handbook (8) is a detailed guide to be used by ESD personnel responsible for seeing that reliability, maintainability and product assurance are included in ESD acquisition contracts. It is an implementation instruction manual for ESDR 800-5 and seems very complete in the areas it addresses.

For most programs the reliability related tasks are stated/defined in MIL-STD-785B, Reliability Program For Systems and Equipment Development and Production (18). MIL-STD-785B contains 18 tasks. Each task states the purpose, gives a description of what is to be accomplished and lists "DETAILS TO BE SPECIFIED BY THE PA [procuring activity] (REFERENCE 1.2.2.1)" (18). The reference refers to the paragraph in the beginning of the standard which states that all tasks must be tailored and is found in every task. This standard is used as a framework for this project.

MIL-STD-1543A (USAF), Reliability Program Requirements for Space and Missile Systems (17), is the reliability standard for space and missile systems. This document uses requirements (rather than tasks) specified for the individual phases of the program to implement reliability procedures. The difference between this standard and the DOD MIL-STD-785B is primarily in the formats. MIL-STD-1543A uses a narrative format versus the lists used by 785B. The same areas of reliability are covered in both, while the space requirements are more specifically designed for space systems.

Other Relevant Publications

This section presents an overview of various publications found to be useful for this thesis and/or for the formulating of a contract.

Reliability and Maintainability Action Plan R&M 2000 (16) includes six major objectives:

> I. Establish clear direction for R&M improvement through visible goals and policy to increase combat effectiveness and operational supportability.
>
> II. Establish an organizational infrastructure to implement the essential elements of the R&M improvement program, to form a base of technical expertise, and to build advocacy, authority, and accountability into the R&M program.
>
> III. Establish an R&M planning system to consolidate R&M efforts, tie R&M to operational goals, and ensure coordination across commands, systems, and technologies.
>
> IV. Establish a system to ensure accountability, review, and feedback on the direction and progress of the R&M program.
>
> V. Establish a communication and motivation program to sustain the commitment to and organizational support for the R&M improvement effort.
>
> VI. Establish industry commitment to R&M to ensure contractors have the motivation and capability to support Air Force R&M requirements. (16:1)

The sixth is most applicable to this thesis. The stated purpose of Objective VI is to ensure "internal planning, requirements documents and review efforts demand and support high priority for R&M" (16:11). To achieve this objective the Air Force must ensure "the specification, statement of work, and proposal and evaluation factors are clear expressions of the level of Air Force commitment and priority for R&M" (16:11).

RADC-TR-79-200, "Reliability and Maintainability Management Manual" (2), is a useful guidebook which covers reliability and maintainability elements of a complete program from concept to deployment. It is a general guide but thorough in its treatment of all the various applications for reliability throughout the life cycle of an acquisition program.

Lessons Learned Bulletin on Reliability and Maintainability (9), published by Air Force Acquisition Logistics Center (AFALC), is a compilation of various programs that have been found to be deficient in various areas including R&M. Anyone about to embark on an acquisition project should peruse this publication so as not to encounter similar mistakes.

The Computer Generated Acquisition Documents System (CGADS) (20) was developed by ESD to help simplify and standardize the contracting process for ESD in addition to implementing ESDR 800-5. The developers of CGADS state that

> levying a task by citing a document (E.G., MIL-SPEC) and paragraph numbers is sufficient. Citing a data item in parantheses; E.G., (DI-A-1001) is all that is allowed for stating that a report is required. Do not add preparation and other delivery requirements! (20:1)

The CGADS system gives a good format/outline for a contract. The system lists most of the references and DID's that may be cited, while not attempting to specify the details for each required reliability task. The instructions state that tailoring of the applicable task is necessary and leaves that aspect up to the originator/writer of the contract.

Product Assurance and Test Engineers Contracting Handbook (25) is a guide intended for use by

> Product Assurance and Test (PA&T) Engineers with guidance and implementation materials for use in the preparation of tailored Reliability...work statements appropriate for incorporating in contracts and RFP's (25:ii).

Overall this document was found to be useful and is recommended for use by anyone tasked with writing reliability requirements in a SOW (with slight grammatical rearrangement). This is the document that prompted the change of focus for this thesis.

MIL-HDBK-338, Electronic Reliability Design Handbook is an extensive compilation of reliability oriented information.

> This handbook describes a comprehensive methodology covering all aspects of electronic system reliability design engineering and cost analysis as they relate to the design acquisition and deployment of DOD equipment/systems (12:iii).

Section 12 of the handbook, the area of most interest for this thesis, discussed the specific program tasks recommended by MIL-STD-785B. However the discussion is limited in that each task is explained simply by several exerpts directly from 785B. But the section titled "Quantitative example of the use of weighting criteria to determine relative program emphasis" (12: Sec 12, 39) was quite useful and used as a model for the tables developed for this thesis. This area included information not covered in other publications.

III. MIL-STD-785B Reliability Tasks

This chapter discusses each task of MIL-STD-785B. The tasks are described in relation to their purposes.

Task 101 - Reliability Program Plan

Task 101 requires the contractor to provide a plan for his Reliability Program. The plan shows that the contractor understands the reliability requirements and describes how he intends to design and/or build a reliable item.

Task 102 - Monitor/Control of Subcontractors and Suppliers

Task 102 requires the prime contractor to ensure that his subcontractors and parts suppliers will meet reliability requirements and that provisions are made for surveillance of their reliability activities. The prime contractor needs insight into what the subcontractors are doing for the final reliability is the prime's responsibility.

Task 103 - Program Reviews

Task 103 concerns formal reviews and assessments of contract reliability requirements. It states specific aspects of the program that should be addressed at each of the five major types of reviews:

Preliminary Design Review (PDR)
Critical Design Review (CDR)
Reliability Program Reviews
Test Readiness Review
Production Readiness Review.

Usually the reliability reviews are included as part of major reviews of the program and is so stated in the Statement of Work (SOW).

Reviews should reveal any problems that may be present in the program and keep the program manager updated so that he is assured all contractual reliability requirements are being met.

If an acquisition program has reliability aspects, then some reliability reviews should be included. For critical systems, reliability is an essential issue at both the Preliminary Design Review (PDR) and the Critical Design Review (CDR), and thus this task would be a requirement starting with FSED or earlier.

Task 104 - Failure Reporting, Analysis, and Corrective Action System (FRACAS)

The FRACAS requires a contractor to develop a "closed loop system" (12: Sec 12, 34; C4:171,210) that collects data on failed items, analyses the failure and documents the corrective action taken to fix the failure.

The closed loop aspect refers to the fact that the analysis of the failure, and the corrective action are monitored to ensure a timely and complete fix. A well designed and utilized FRACAS will assist in reliability growth and identify problems during Task 302, Reliability Development/Growth Testing.

Task 105 - Failure Review Board (FRB)

The FRB is responsible for reviewing failures, assigning failure causes, and monitoring the FRACAS to ensure failures are analyzed and the corrective action is adequate. The contractor must appoint members to the board from design, reliability, safety, manufacturing and quality assurance to investigate failures. The FRB consists of contractor personnel with an AF representative as an observer.

To avoid redundancy with other quality functions, primarily the Material Review Board, "this task shall be coordinated with Quality Assurance organizations to insure there is no duplication of effort" (18: Sec 105, 1). Normally all programs with a FRACAS also have this task.

Task 201 - Reliability Modeling

> A reliability model is a mathematical equation which defines the relationship between the failure rate of an assembly (equipment, or system) and the failure rate of all the parts which make up the assembly (1:46).

The task requires the contractor to develop and update reliability models using techniques defined in MIL-HDBK-217. Models provide the framework for the allocations and predictions (Tasks 202 and 203) of reliability.

Task 202 - Reliability Allocations

Reliability allocation apportions, or gives, to each subsystem a reliability goal based on the total system reliability requirement.

Requiring this task can be helpful for establishing baseline requirements for subsystem designs. Since the prime contractor does not usually supply every subsystem, this task also establishes the reliability requirement for subcontracted material. Any parts supplied by government furnished equipment (GFE), vendors or subcontractors need to conform to the total system reliability.

Task 203 - Reliability Predictions

A reliability prediction is an estimate of the reliability of your system, based on historical data from similar parts, assemblies or systems. The longer the component has been in operation and failure rate data has been collected, the better future predictions will be. The reliability prediction of Task 203 requires the contractor to develop predictions of whole assembly reliability based on the failure rates of component parts. However if failure rates have not yet been determined, as in the conceptual phase, and many unique parts are to be used, (not a good idea - as many off the shelf/GFE parts as possible should be used) other predictive techniques need to be developed.

Predictions and allocations are used by Logistics Support Analysis (LSA) in order to determine the required number of spares, maintenance people, facilities, and life cycle cost.

Task 204 - Failure Modes, Effects, and Criticality Analysis (FMECA)

As a result of Task 204 the designer determines possible failures of a design and the effects of those failures on the total system performance. FMECA is "a companion effort along with reliability modeling, prediction, allocation and design" (2:48). If possible problems are identified early by a FMECA, the corrective design changes can be easily implemented with least cost.

Task 205 - Sneak Circuit Analysis

A Sneak Circuit Analysis (SCA) determines the various paths a circuit might take and what effects on the system unwanted signals might make. An example of a sneak circuit might be: a circuit designed to raise the landing gear will inadvertently be triggered if the pilot were to turn on all the lights in a certain order. This is a possibly disastrous occurrence if the aircraft were traveling down the runway.

SCA is expensive to accomplish, therefore, should be reserved for critical systems: flight and weapon controls, space application, etc. in order to identify

> designed-in conditions that could inhibit desired system functions or produce undesired system functions which could adversely affect crew safety or mission equipment (1:iii).

RADC-TR-82-179, "Sneak Analysis Application Guidelines" (1) is a comprehensive report derived from the investigation of numerous projects where SCA had been applied. This report gives guidelines about when and on what types of systems SCA should be applied.

A SCA should be done as early as possible in the acquisition cycle, but

> Since Sneak Analysis is based on detailed system drawings and computer program instructions, the most likely early phases for implementation would be the Full-Scale Engineering Development and Full-Scale Prototype Development phases (1:6).

If sneak circuit problems can be identified early, design changes are easier and less costly to implement.

Task 206 - Electronic Parts/Circuits Tolerance Analysis

An electronic tolerance analysis analyzes the effects that design parameters of a system will have on electronic parts and circuits. A good design will be tolerant of a range of parameters. Since a great many factors must be taken into consideration, Task 206 is costly and recommended only for critical systems.

Task 207 - Parts Program

Task 207 requires the contractor to develop a comprehensive program that identifies all parts and controls the acquisition of parts so that reliability is assured. The stated objective of this task is "to control the selection and use of standard and nonstandard parts" (18:A12) with the underlying objective being "to ensure that the contractor will select, whenever possible, standard military parts of the preferred type and quality" (19:67). Most military parts are already tested, and approved. Using nonstandard parts can increase the acquisition cost of a program because of the need for their design, test and approval. In addition, nonstandard parts increase the number of spare parts maintained in the Air Force inventory. A parts program is expensive, however if the program is effective, the reduced LCC will compensate for the original investment.

Task 208 - Reliability Critical Items

Task 208 requires the contractor to identify the subsystems/components that are so critical that their failure would cause the whole system to fail. The Task also specifies the necessity for the identification of "methods and procedures for control and testing of (those) reliability critical items" (18: Sec 208, 1). The inputs to this task come from the FMECA or other analysis.

Task 209 - Effects of Functional Testing, Storage, Handling, Packaging, Transportation, and Maintenance (PHT)

Task 209 requires the contractor to develop procedures to identify what effects PHT will have on the system. Normally this item should be handled by PHT engineers and care needs to be taken that the contractor does not charge twice for the same work if this task is required.

Task 301 - Environmental Stress Screening (ESS)

ESS requires the contractor to "establish and implement...procedures" (18: Sec 301, 1) to identify and remove bad parts and workmanship. This 'burn-in' usually consists of short duration tests that severely stress a component beyond its expected normal operating environment with the intent to stimulate failures. Parts, subassemblies and complete units are subjected to shock, vibrations, extreme heat, cold, dust, sand, and nuclear radiation under the most severe situations that components would ever be expected to encounter.

> Regardless of time or cost, environmental testing is an essential part of any reliability program and not a safe place to look for 'money-saving' shortcuts. The life cycle cost penalty can dwarf any development cost saving. (2:62)

Task 302 - Reliability Development/Growth Test (RDGT) Program

Usually the initial reliability predictions are not achieved in the prototype or even during FSED. By using the RDGT concept, failures are expected. When they occur, the failures are analyzed and corrective action is taken as applicable. This testing, finding and correcting of failures will improve reliability over time (this is reliability growth).

Task 3Ø3 - Reliability Qualification Test (RQT) Program

Task 3Ø3 requires the contractor prove the system is ready for production, in that it meets the 'minimum' reliability requirement. The RQT is a one time test to demonstrate the reliability required in the specification.

Task 3Ø4 - Production Reliability Acceptance Test (PRAT) Program

The PRAT program is an ongoing effort throughout production. The program consists of periodically testing, in a simulated operational environment, components from production. The test is to verify that the production units continue to meet reliability requirements.

IV. Cost Effectiveness and Application Analysis

This chapter discusses the cost effectiveness (C/E) of the reliability tasks in MIL-STD-785 and discusses the application of the tasks according to program phase. Two examples of how to determine the relative C/E of the tasks for a particular acquisition program are presented. The question of whether to require a contractor to accomplish the tasks is subjectively answered.

Background

The primary reason any reliability task should be required is to acquire a reliable system. However every acquisition program has cost constraints, and each extra requirement on the contractor exacts a cost. Therefore some sort of cost analysis should be performed.

A C/E influences table from MIL-HDBK-338 (12: Sec 12, 40) was used as a model for analysis of the cost effectiveness of MIL-STD-785B tasks. The table is used to rate relative cost effectiveness of a task (on a scale from 1 to 5) based on the following major criteria; complexity of design, equipment criticality, quantity purchased, equipment operating environment, level of technology and storage requirements. Each major criterion is scaled according to two factors. For example, complexity is either high or low, technology is standard or state of the art.

Empty tables were given to AF Institute of Technology (AFIT) reliability instructors and to reliability engineers in Aeronautical Systems Division (ASD) and AF Acquisition Logistic Center (AFALC) with instructions that they were to subjectively fill in the numbers, ie. how they 'felt' the cost effectiveness was for each task. Tables I through III are the averaged results of the responses. The tables show a wide diversity of opinion as to the cost effectiveness of many of the individual tasks. Some respondents had mostly very low numbers, while one respondent hardly discriminated at all, giving a preponderance of fives to most of the tasks. Evidently he was of the opinion all the tasks under every criteria are very cost effective.

Cost Effectiveness Analysis

In this section each of the three tables are discussed. The discussion focuses on the average numbers as shown by the tables. The method for general evaluation of the tables was to sum all the numbers for each task (across the tables). The highest sum thus indicated that task to be most cost effective (C/E). The lowest sums were indicative of those tasks least C/E. Certain criteria (down the columns) which showed a significant consensus were also discussed (ie. Hi Complexity for space and missile systems, Table I, has almost all 4's and 5's).

Table I: Cost Effectiveness Influences For Space and Missile Systems. The tasks deemed most cost effective for space and missile systems are Tasks 104 and 105, Failure Reporting, Analysis and Corrective Action System (FRACAS) and Failure Review Board (FRB). Tasks 207 and 301, Parts Program and ESS, also have relatively high scores. The emphasis seemed to be placed on controlling part reliability, through the parts program, screening the parts and then using failure data to highlight the remaining problems.

The Reliability Program Plan, Task 101 has the lowest total average score, with Tasks 205, 303 and 304 (Sneak Circuit Analysis (SCA), Reliability Qualification Test (RQT), and Production Reliability Acceptance Test PRAT)) also having low numbers.

It is also apparent that it would be considered cost effective to require almost all of the tasks for items of high complexity and criticality using technology that is pushing the state of the art (SOA).

Requiring a program plan is primarily a paperwork exercise and if cost is indeed a constraint (every piece of paper required costs upward of $50) then this task may be the first to be eliminated. The RQT may not be cost effective but is usually required (called a Qual test) for space systems and there is at least one occasion where the Qual test satellite was actually sent into orbit. The PRAT is another test that is nice to have but may not be cost

TABLE I

COST EFFECTIVENESS INFLUENCES
FOR SPACE AND MISSILE SYSTEMS

Task	Title	Complexity		Equipment Crit.		Quantity		Equip. Oper. Environment		Technology		Storage	
		Lo	Hi	Lo	Hi	Lo	Hi	Benign	Hostile	Std	SOA	Short	Long
101	Rel. Program Plan	1	3	2	4	2	3	2	3	2	3	2	3
102	Mon./Control Subs & Sups	3	4	3	4	2	4	3	3	2	4	2	3
103	Program Reviews	3	4	3	4	3	3	3	3	2	4	2	3
104	FRACAS	3	5	3	5	4	4	3	4	3	4	3	3
105	Failure Review Board (FRB)	3	5	3	5	4	4	3	4	3	4	3	3
201	Reliability Modeling	3	4	2	4	2	2	3	3	2	4	2	3
202	Reliability Allocations	2	4	2	4	3	3	3	3	2	4	2	3
203	Reliability Predictions	2	4	3	4	3	3	2	3	3	3	2	3
204	FMECA	2	4	2	5	3	3	3	4	3	4	2	3

TABLE I (CONT.)

COST EFFECTIVENESS INFLUENCES
FOR SPACE AND MISSILE SYSTEMS (CONT.)

Task	Title	Complexity		Equipment Crit.		Quantity		Equip. Oper. Environment		Technology		Storage	
		Lo	Hi	Lo	Hi	Lo	Hi	Benign	Hostile	Std	SOA	Short	Long
205	Sneak Circuit Analysis(SCA)	2	4	1	5	2	3	2	3	3	4	2	2
206	Elec. Parts/ Ciruits Tolerance Analysis	2	4	2	4	2	3	2	4	2	4	2	3
207	Parts Program	4	5	3	5	2	4	3	4	3	4	3	3
208	Reliability Critical Items	2	4	2	4	3	3	2	4	2	4	2	2
209	PHT	2	3	3	4	3	3	2	3	2	4	2	3
301	Envir. Stress Screening(ESS)	3	5	3	5	3	4	3	4	3	4	3	3
302	Rel. Dev/Grow Test (RDGT)	2	4	3	4	3	3	2	3	3	4	2	4
303	Rel. Qual. Test (RQT)	2	3	2	4	2	2	2	3	3	4	2	2
304	Product. Rel. Accept. Test (PRAT) Program	2	4	2	4	2	4	3	3	2	3	2	2

effective. However when it is not required, the production items will be operationally tested in the field with possibly disastrous results.

The cost effectiveness of SCA does not rate very high in all three tables. If a SCA is required, critical systems need a more sophisticated and complete analysis then less critical systems; however, the more parts and paths involved the higher the cost. Figure 1 gives a rough estimate in graphical form of the escalating cost of a SCA according to the number of parts.

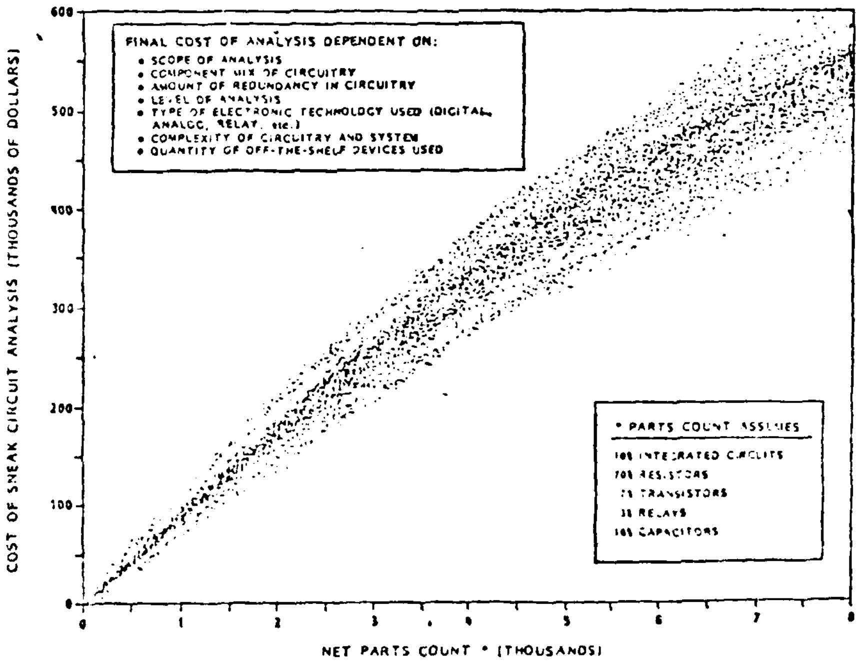

Figure 1. Relative Cost of SCA

Table II: Cost Effectiveness Influences For Avionics Electrical Equipment. Environmental Stress Screening (ESS) and a Parts Program (Tasks 301 and 207) seem to be thought most cost effective across the board while Tasks 209 and 103 (Effects of Functional Testing, Storage, Handling, Packaging, Transportation, and Maintenance (PHT) and Program Reviews) least C/E. Again complex and critical systems have high scores for almost all tasks. Pushing the SOA does not seem to have as much weight as it does for space and missile systems.

Usually program reviews take up valuable time both from the contractor and AF program management staffs. The reliability reviews should be incorporated with total system reviews. If the reviews are planned for in advance, with data being accumulated and peridically analyzed with reviews in mind, they should not require an extraordinary effort.

Some engineers believe Task 209 (PHT) should not really fall under the responsibility of reliability but belongs in another area.

TABLE II

COST EFFECTIVENESS INFLUENCES
FOR AVIONICS/ELECTRICAL EQUIPMENT

Task	Title	Complexity		Equipment Crit.		Quantity		Equip. Oper. Environment		Technology		Storage	
		Lo	Hi	Lo	Hi	Lo	Hi	Benign	Hostile	Std	SOA	Short	Long
101	Rel. Program Plan	2	4	2	4	2	3	2	3	2	3	2	4
102	Mon./Control Subs & Sups	2	4	2	4	2	4	2	4	3	4	2	3
103	Program Reviews	2	3	2	3	2	3	2	3	2	3	2	2
104	FRACAS	3	4	3	4	3	4	3	4	3	4	3	4
105	Failure Review Board (FRB)	2	4	2	5	3	4	3	4	3	4	3	3
201	Reliability Modeling	2	4	2	4	2	3	2	3	3	3	2	3
202	Reliability Allocations	2	4	2	4	3	3	3	3	3	3	3	3
203	Reliability Predictions	3	4	3	4	3	3	3	4	3	4	2	3
204	FMECA	2	4	2	5	3	3	2	3	3	4	3	4

TABLE II (CONT.)

COST EFFECTIVENESS INFLUENCES
FOR AVIONICS/ELECTRICAL EQUIPMENT (CONT.)

Task	Title	Complexity		Equipment Crit.		Quantity		Equip. Oper. Environment		Technology		Storage	
		Lo	Hi	Lo	Hi	Lo	Hi	Benign	Hostile	Std	SOA	Short	Long
205	Sneak Circuit Analysis(SCA)	1	4	1	5	2	3	2	4	2	3	2	3
206	Elec. Parts/ Ciruits Tolerance Analysis	2	4	2	4	1	3	1	4	2	3	2	3
207	Parts Program	3	4	3	5	3	4	3	4	3	4	3	4
208	Reliability Critical Items	2	4	2	4	2	3	2	3	2	4	2	3
209	PHT	2	3	2	3	2	3	2	2	2	3	2	2
301	Envir. Stress Screening(ESS)	3	5	3	5	3	4	3	4	3	4	3	3
302	Rel. Dev/Grow Test (RDGT)	2	5	2	4	2	4	2	4	3	4	3	3
303	Rel. Qual. Test (RQT)	2	4	2	4	3	3	2	4	3	4	2	3
304	Product. Rel. Accept. Test (PRAT) Program	2	4	2	4	2	4	2	3	3	3	2	2

Table III: Cost Effectiveness Influences For Airframe/ Mechanical Equipment. Program Reviews, FRACAS and a Parts Program (Tasks 103, 104 and 207) were determined to be most cost effective for airframe/mechanical equipment. Tasks 205 and 206 (SCA and Electronic Parts/Circuits Tolerance Analysis) were found to be least C/E. Since Tasks 205 and 206 deal with electronic systems, it seems logical that these two tasks would not be C/E for mechanical or airframe equipment.

The three criteria: high complexity, high equipment criticality and SOA Technology continue to rate higher for most of the Tasks then do the other criteria, but in relation to the two previously discussed charts there is an overall lower ranking.

TABLE III

COST EFFECTIVENESS INFLUENCES
FOR AIRFRAME/MECHANICAL EQUIPMENT

Task	Title	Complexity		Equipment Crit.		Quantity		Equip. Oper. Environment		Technology		Storage	
		Lo	Hi	Lo	Hi	Lo	Hi	Benign	Hostile	Std	SOA	Short	Long
101	Rel. Program Plan	1	4	1	4	2	3	2	4	2	3	2	3
102	Mon./Control Subs & Sups	2	4	2	4	2	3	2	3	2	4	2	2
103	Program Reviews	3	4	3	4	3	3	3	4	3	4	2	3
104	FRACAS	3	4	3	5	3	4	3	4	3	4	3	3
105	Failure Review Board (FRB)	2	4	2	4	2	3	2	4	2	4	3	3
201	Reliability Modeling	2	3	2	3	2	3	2	3	2	3	2	3
202	Reliability Allocations	2	4	2	4	2	2	3	3	2	3	2	3
203	Reliability Predictions	2	4	2	4	2	2	2	3	2	3	2	3
204	FMECA	2	4	2	5	2	3	2	4	3	4	3	3

TABLE III (CONT.)

COST EFFECTIVENESS INFLUENCES
FOR AIRFRAME/MECHANICAL EQUIPMENT (CONT.)

Task	Title	Complexity		Equipment Crit.		Quantity		Equip. Oper. Environment		Technology		Storage	
		Lo	Hi	Lo	Hi	Lo	Hi	Benign	Hostile	Std	SOA	Short	Long
205	Sneak Circuit Analysis(SCA)	1	3	1	3	2	2	1	2	2	3	1	2
206	Elec. Parts/ Ciruits Toler-ance Analysis	1	3	1	3	2	2	2	2	2	2	1	2
207	Parts Program	3	4	3	4	2	4	3	4	3	3	2	3
208	Reliability Critical Items	2	4	2	4	2	3	2	3	2	3	2	3
209	PHT	2	3	2	4	2	3	2	3	2	3	2	3
301	Envir. Stress Screening(ESS)	2	3	2	4	2	3	2	3	2	3	2	2
302	Rel. Dev/Grow Test (RDGT)	2	4	2	4	2	3	2	4	3	4	2	2
303	Rel. Qual. Test (RQT)	1	4	1	4	2	3	2	3	2	3	1	2
304	Product. Rel. Accept. Test (PRAT) Program	2	3	2	4	2	4	2	3	2	3	2	2

Determination of Task Cost Effectiveness

The following few pages will show two examples of how the C/E tables can be used. The first step in using the tables, is to categorize a piece of equipment according to the criteria. Figure 2 is an example of categorizing a particular piece of equipment. In this case a cockpit lighting system.

Cockpit Lighting System

Complexity	-	Low
Equip Criticality	-	Low
Quantity	-	Hi
Equip Oper. Environment	-	Benign
Technology	-	Standard
Storage Time	-	Short

Figure 2. Categorization of Equipment

A matrix is then developed (Table IV) by taking the appropriate numbers from the applicable cost effectiveness table for each criteria and each task. Because this is electrical equipment, Table II is used. Each of the numbers for a task is multiplied to determine a total weighting factor (ie. for Task 101 multiply 2 X 2 X 3 X 2 X 2 X 2 = 96). Using a scale such as 20 (or 10, 30 etc.), the highest number, 972, is given a weighting factor of 20. The next subsequent lower number is divided by the highest (486/972 = .5) and multiplied by 20 (20 X .5 = 10) to get a weighting

Table IV

Cockpit Lighting C/E Matrix

	Comp	Crit	Quan	Envir	Tech	Store		
Task	Lo	Lo	Hi	Benign	Std	Short	Total	Factor
101	2	2	3	2	2	2	96	2
102	2	2	4	2	3	2	192	4
103	2	2	3	2	2	2	96	2
104	3	3	4	3	3	3	972	20
105	2	2	4	3	3	3	432	9
201	2	2	3	2	2	2	96	2
202	2	2	3	3	3	3	324	6.7
203	3	3	3	3	3	2	486	10
204	2	2	3	2	3	3	216	4.4
205	1	1	3	2	2	2	24	.5
206	2	2	3	1	2	2	48	1
207	3	3	4	3	3	3	972	20
208	2	2	3	2	2	2	96	2
209	2	2	3	2	2	2	96	2
301	3	3	4	3	3	3	432	9
302	2	2	4	2	3	2	192	4
303	2	2	3	2	3	2	144	3
304	2	2	4	2	3	2	192	4

factor of 10. The rating for each task is achieved the same way.

The major emphasis for the lighting system should be on Tasks 104 and 207 (FRACAS and Parts Program) as they have the highest weighting factor of 20. Tasks 203, 105 and 301 (Reliability Predictions, FRB and ESS) might also be considered with their factors of 10, 9 and 9.

The least C/E tasks would be 205 and 206 (SCA and Electronic Parts/Circuits Tolerance Analysis). For a simple system those two tasks would most likely cost much more than they are worth. Tasks 101, 103, 201, 208 and 209 (Program Plan, Program Reviews, Reliability Modeling, Reliability Critical Items, and PHT) also rate low with factors of 2. These last five tasks are paperwork exercises that can be useful for critical systems but may not be C/E for simple systems.

Another example of using the C/E tables might be for a complex airborne missile system. Figure 3 shows the categorization by criteria and Table V gives a C/E matrix for this missile system. For this example Table I, Cost Effectiveness Influences for Space and Missile Systems, is used.

Airborne Missile System

Complexity	-	Hi
Equip Criticality	-	Hi
Quantity	-	Low
Equip Oper. Environment	-	Hostile
Technology	-	SOA
Storage Time	-	Long

Figure 3. Categorization of Equipment

As in the previous example each of the numbers for a task are multiplied to determine a total weighting factor (ie. for Task 101 multiply 3 X 4 X 2 X 3 X 3 X 3 = 648). A rating of 20, is given to the highest number, 4800. The next subsequent lower number is divided by the highest (3600/4800 = .75) and multiplied by 20 (20 X .75 = 15) to get a rating of 15. The process is continued for each task to get the lower factors.

The major emphasis for the Airborne Missile System should be on Tasks 104, 105 and 301 (FRACAS, FRB and ESS) as they have the highest weighting factors of 20, 20, and 15. Tasks 204 and 207 (FMECA and Parts Program) also score fairly high with factors of 12 and 10 respectively.

Table V

Airborne Missile System C/E Matrix

Task	Comp Hi	Crit Hi	Quan Lo	Envir Hostile	Tech SOA	Store Long	Total	Factor
101	3	4	2	3	3	3	648	2.7
102	4	4	2	3	3	3	864	3.6
103	4	4	3	3	4	3	1728	2
104	5	5	4	4	4	3	4800	20
105	5	5	4	4	4	3	4800	20
201	4	4	2	3	4	3	1152	4.8
202	4	4	3	3	4	3	1728	7.2
203	4	4	3	3	3	3	1296	5.4
204	4	5	3	4	4	3	2880	12
205	4	5	2	3	4	2	960	.4
206	4	4	2	4	4	3	1536	6.4
207	5	5	2	4	4	3	2400	10
208	4	4	3	4	4	2	1536	6.4
209	3	4	3	3	4	3	1728	2
301	5	5	3	4	4	3	3600	15
302	4	4	3	3	4	2	1152	4.8
303	3	4	2	3	4	2	576	2.4
304	4	4	2	3	3	2	576	2.4

It should be remembered that Tables I through III are composites of subjective numbers applied according to the various criteria for the different reliability tasks. These numbers were gathered from experts in reliability working at Wright Patterson AFB, each of whom has his own biases. These numbers and criteria are subjective and, as MIL-HDBK-338 states, "each manager may want to develop his own weighting factors criteria and the specific numbers for his given application" (12:Sec 12, 41).

Application Analysis

In this section the four major acquisition phases and the applicability of the reliability tasks within each phase are discussed.

The tools used for the task applicability analysis are the Application Matrix (Figure 4) taken from MIL-STD-785B and the Reliability Program Elements chart (Figure 5) (available in several publications) which shows criticality of reliability tasks in relation to the acquisition life cycle phases.

TASK	TITLE	TASK TYPE	PROGRAM PHASE			
			CONCEPT	VALID	FSED	PROD
101	RELIABILITY PROGRAM PLAN	MGT	S	S	G	G
102	MONITOR/CONTROL OF SUBCONTRACTORS AND SUPPLIERS	MGT	S	S	G	G
103	PROGRAM REVIEWS	MGT	S	S(2)	G(2)	G(2)
104	FAILURE REPORTING, ANALYSIS, AND CORRECTIVE ACTION SYSTEM (FRACAS)	ENG	NA	S	G	G
105	FAILURE REVIEW BOARD (FRB)	MGT	NA	S(2)	G	G
201	RELIABILITY MODELING	ENG	S	S(2)	G(2)	GC(2)
202	RELIABILITY ALLOCATIONS	ACC	S	G	G	GC
203	RELIABILITY PREDICTIONS	ACC	S	S(2)	G(2)	GC(2)
204	FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)	ENG	S	S (1)(2)	G (1)(2)	GC (1)(2)
205	SNEAK CIRCUIT ANALYSIS (SCA)	ENG	NA	NA	G(1)	GC(1)
206	ELECTRONIC PARTS/CIRCUITS TOLERANCE ANALYSIS	ENG	NA	NA	G	GC
207	PARTS PROGRAM	ENG	S	S(2)(3)	G(2)	G(2)
208	RELIABILITY CRITICAL ITEMS	MGT	S(1)	S(1)	G	G
209	EFFECTS OF FUNCTIONAL TESTING, STORAGE, HANDLING, PACKAGING, TRANSPORTATION, AND MAINTENANCE	ENG	NA	S(1)	G	GC
301	ENVIRONMENTAL STRESS SCREENING (ESS)	ENG	NA	S	G	G
302	RELIABILITY DEVELOPMENT/GROWTH TESTING	ENG	NA	S(2)	G(2)	NA
303	RELIABILITY QUALIFICATION TEST (RQT) PROGRAM	ACC	NA	S(2)	G(2)	G(2)
304	PRODUCTION RELIABILITY ACCEPTANCE ACCEPTANCE TEST (PRAT) PROGRAM	ACC	NA	NA	S	G(2)(3)

CODE DEFINITIONS

TASK TYPE

ACC - RELIABILITY ACCOUNTING

ENG - RELIABILITY ENGINEERING

MGT - MANAGEMENT

PROGRAM PHASE

S - SELECTIVELY APPLICABLE

G - GENERALLY APPLICABLE

GC - GENERALLY APPLICABLE TO DESIGN CHANGES ONLY

NA - NOT APPLICABLE

(1) - REQUIRES CONSIDERABLE INTERPRETATION OF INTENT TO BE COST EFFECTIVE

(2) - MIL-STD-785 IS NOT THE PRIMARY IMPLEMENTATION REQUIREMENT. OTHER MIL-STDS OR STATEMENT OF WORK REQUIREMENTS MUST BE INCLUDED TO DEFINE THE REQUIREMENTS.

Figure 4. Application Matrix

	Life Cycle Phase				
	Conceptual	Validation	Full Scale Development	Production	Deployment
Requirements Definition	xxxxxxxxxxx	xxxxxAAAAAA	....		
Reliability Model	xxxxxx	xxxxxxxxxxxx	xxx......		
Reliability Prediction	xxxxxx	xxxxxxxxxxxx	xxx......		
Reliability Apportionment	oooooo	oooooooooooo	ooo......		
Failure Modes Analysis	oooooo	ooooooooooxx	xxxx......		
Design for Reliability	oooooo	xxxxxxxxxxx	xxxxxxxxx...	....	
Parts Selection	oooooo	xxxxxxxxxxAA	AAAA.........	....	
Design Review	oooooo	xxxxxxxxxxx	xxxx......		
Design Specifications	xxxxxxxx	xxxxxxxxxxx	....		
Acceptance Specifications	xxxx	xxxxxxxAAAAA	....		
Reliability Evaluation Tests	----	xxxxxxxxxxx	xxxxx		
Failure Analysis	----	xxxxxxxxxxx	xxxxxxxxxxooo	oooooooooo	ooooooo
Data System	----	xxxxxxxxxxx	xxxxxxxxxxooo	oooooooooo	ooooooo
Quality Control		ooooooooooxx	xxxxxxxxxxxx	xxxxxxxxooo	ooooooo
Environmental Tests		xxxxx.	.....AAAAAAA	....	
Reliability Acceptance Tests		xx.	......AAAAAo	ooooooo	

First contract

KEY

------ Desirable activity (for highest success probability)

oooooo Necessary activity (errors seldom disastrous)

xxxxxx Very important activity (errors usually disastrous)

...... Low key activity (to update previous results)

AAAAAA Critical Activity

Figure 5. Reliability Program Elements

Concept Phase. The concept phase is the time during which alternatives are proposed to meet a particular threat and satisfy a particular need. Often more than one contractor will be tasked to work on the concept, in order to have at least two original designs ("competitive exploration of alternatives" (23: Sec IV, 1).

Very few of the reliability tasks are actually applicable during this phase since the design is still being formulated. The program manager must be considering reliability and the contractor must also be designing for reliability, but usually only tasks 201 and 203, Reliability Modeling, and Reliability Predictions are applicable. These models and predictions will undoubtedly "be rather crude during the conceptual phase, it (they) will be expanded and refined as more system details are evolved" (2:46).

Reliability Predictions were not rated as very cost effective on any of the three C/E tables; however, predictions can prevent disastrous results as depicted by the Reliability Program Elements chart, Figure 5. This chart shows prediction to be a very important activity during the later half of conceptual stage, throughout validation and into FSED. Errors here are usually disastrous. If predictions of reliability for component parts do not come true, then the reliability of the whole system will be effected.

Demonstration/Validation Phase.

> In the Demonstration and Validation phase, definitization of the selected alternative(s) is expanded, and the value and practicality of the increasingly specific design approach continues to be checked (23: Sec VI, 1).

In this phase a Program Plan, Task 101 could be required of the competitors so that they could show what they plan to do if awarded the contract; however, since program plans are not deemed C/E, this task may not be required at least on the more cost constrained programs. Modeling and Predictions would continue from the Concept Phase and be revised and updated as appropriate. Reliability Allocation (Task 202) could begin, for the major subsystems would now be identified. Also Reliability Critical Items (Task 208) and FMECA (Task 204) could be required, realizing further refinement would be necessary during FSED.

Full Scale Engineering Development (FSED). The FSED is the phase where the 'final' design is approved and a preproduction prototype is built, tested and approved. It is during this phase that almost all tasks are applicable (if they are applicable/cost effective for a particular program). PRAT (Task 304) is generally not applicable since this task is specifically used to test production items.

Production Phase. The final acquisition phase is the production phase (deployment and phase-out are not part of acquisition) where the object of the first three phases is produced.

The primary task requirement during this phase would be the PRAT program task 304. A limited program plan might also be required from the contractor to update his continuing efforts for reliability. Tasks 102 and 207 (monitoring of subcontractors and the parts program) are also important in this phase to assure there is a continuous supply of reliable parts and subcomponents.

If other 200 level tasks had been required during development, the data and results of tests required by those tasks should be reviewed to verify if the predictions correlate with actual operational reliability (after the first lot from production is operational). Similarly the results from the ESS and the RQT need to be reviewed.

V. Summary, Conclusions, Recommendations

Summary

Simply stating the desired/required reliability for a system in a contract does not guarantee reliability. The majority of individuals questioned by the R&M 2000 working group were of the opinion that management attention was of prime importance. Evidently, management, both Air Force and contractor, must wholeheartedly support and follow through on a reliability program for it to be successful.

While researching various contracts for this paper, a contract was found consisting of at least 75 pages of specifications, SOW and CDRL pertaining to the purchase of a shipping container for some part. In other words, they basically wanted to buy a cardboard box. This author believes the extraordinary paperwork and micro-management can be reduced/eliminated. Indeed it is necessary for the Air Force to specify what is needed, and the conditions and time under which the systems must operate; but increasing the lengths of contracts lengthens the procurement period and increases the acquisition cost.

This research effort focused on the cost effectiveness of the tasks of MIL-STD-785B and discovered several tasks thought to be not cost effective (relative to other tasks). The elimination of some of those tasks (if in fact the elimination of the tasks would indeed not adversely effect the reliability of the final product) from contracts may help to speed up the acquisition process and reduce costs.

Conclusions

The relatively wide range of numbers applied to the cost effectiveness tables by the different engineers reflects a diversity of opinion that could significantly effect acquisition programs. The number of tasks included in a contract depends on the opinions of the writer (reliability engineer) of that contract. One author may wholeheartedly believe every task is important (and therefore cost effective) and include more tasks than absolutely necessary to get the desired reliability. Another writer may not think many of the tasks are of value and he may possibly leave out a necessary task(s).

The cost effectiveness method of rank ordering reliability tasks is only one method of determining what should be included in a contract. This method can help managers prioritize areas for the managing of time and money. It is only one method, and if used, it needs to be used in conjunction with common sense and other methods that may be available.

Having found Columbia Research Corporation's handbook, which is a worthwhile guide to contracting for reliability, a question arises: why isn't it being used? When this project began, it was thought by several experienced persons that there was not available a truly useful guide on how to contract for reliability. Since 1982 Columbia's handbook has been available with little notice.

Recommendations

A possible follow-on topic to this thesis is the investigation of procurements, to discover if there are any contracts with a minimal amount of specifications and requirements and what (if any) deleterious effects there are on reliability and effectiveness of the system. Or the reverse case could be investigated. A contract (or contracts) with excessive specifications and requirements could be the object of research to determine if those excesses helped get a better, more reliable product or in fact were only a hindrance. The actual cost of each specification and requirement could be determined and some correlation, of actual cost vs. reliability acquired, might be obtained

In line with the underutilization of publications paid for by DOD and dealing with the government, a topic might be to investigate such publications and determine the actual usage (versus cost) of those publications.

Appendix: Acronyms

AFALC	-	Air Force Acquisition logistics Center
AFSC	-	Air Force Systems Command
AFOTEC	-	Air Force Operational Test & Evaluation Center
ASD	-	Aeronautical Systems Division
AFTEC	-	Air Force Test & Evaluation Center
C/E	-	Cost Effectiveness
CDR	-	Critical Design Review
CDRL	-	Contract Data Requirements List
CERT	-	Combined Environment Reliability Test
DOD	-	Department of Defense
DODD	-	Department of Defense Directive
ESD	-	Electronic Systems Division (AFSC)
ESS	-	Environmental Stress Screening
FMECA	-	Failure Modes and Criticality Analysis
FRACAS	-	Failure Reporting, Analysis and Corrective Action System
FRB	-	Failure Review Board
FSED	-	Full Scale Engineering Development
GFE	-	Government Furnished Equipment
LSA	-	Logistics Support Analysis
LCC	-	Life Cycle Costs
MTBF	-	Mean Time Between Failure
MTBM	-	Mean Time Between Maintenance
MIL-HDBK	-	Military Handbook
MIL-STD	-	Military Standard

PA&T	-	Product Assurance and Test
PHT	-	Effects of Functional Testing, Storage, Handling, Packaging, Transportation and Maintenance
PDR	-	Preliminary Design Review
PRAT	-	Production Reliability Acceptance Test Program
RADC	-	Rome Air Development Center
RFP	-	Request for Proposal
RDGT	-	Reliability Development/Growth Test
RIW	-	Reliability Improvement Warranty
R&M	-	Reliability and Maintainability
RQT	-	Reliability Qualification Test
SCA	-	Sneak Circuit Analysis
SON	-	Statement of Need
SOW	-	Statement of Work

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This thesis analyzed the cost effectiveness of the 18 tasks specified in MIL-STD-785B, Reliability Program for Systems and Equipment Development and Production. The purposes of the tasks are described and each task was evaluated according to six criteria. Cost effectiveness tables were developed for Airframe/Mechanical Equipment, Avionics/Electrical Equipment, and Space and Missile Systems. The tables shows averages taken from surveys completed by reliability instructors teaching at AFIT and reliability engineers employed by Aeronautical Systems Division and Air Force Aquisition Logistics Center. This analysis also includes a discussion of the applicability of the tasks according to program phase.

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